Indicators of Ecological Change

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A SERDP Ecosystem Management Project (SEMP)
being implement at Fort Benning, GA

Brief to the SEMP Technical Advisory Committee
July 18, 2001

Participants

- Jack Feminella, Ken Fritz, Kelly Maloney, and Danny Johns, Department of Biological Sciences, Auburn University — Stream macroinvertebrates
- Thomas Foster, Anthropology Department, Pennsylvania State University — Historical land cover
- Patrick Mulholland, Environmental Sciences Division, Oak Ridge National Laboratory — Aquatic ecology
- Lisa Olsen, Environmental Sciences Division, Oak Ridge National Laboratory -- Geographic information and landscape analysis
- David White, Aaron Peacock, and Sarah McNaughton, Center for Environmental Technology, University of Tennessee — Soil microbiology
- Suzanne Beyeler, Institute for Environmental Studies, Miami University, Ohio — Terrestrial indicators

Objectives

- To identify indicators that signal ecological change in intensely versus lightly used ecological systems.

- To ensure that these indicators are feasible for the installation staff to measure and interpret and thus can become a part of the ongoing monitoring system at the installation.

Technical Approach

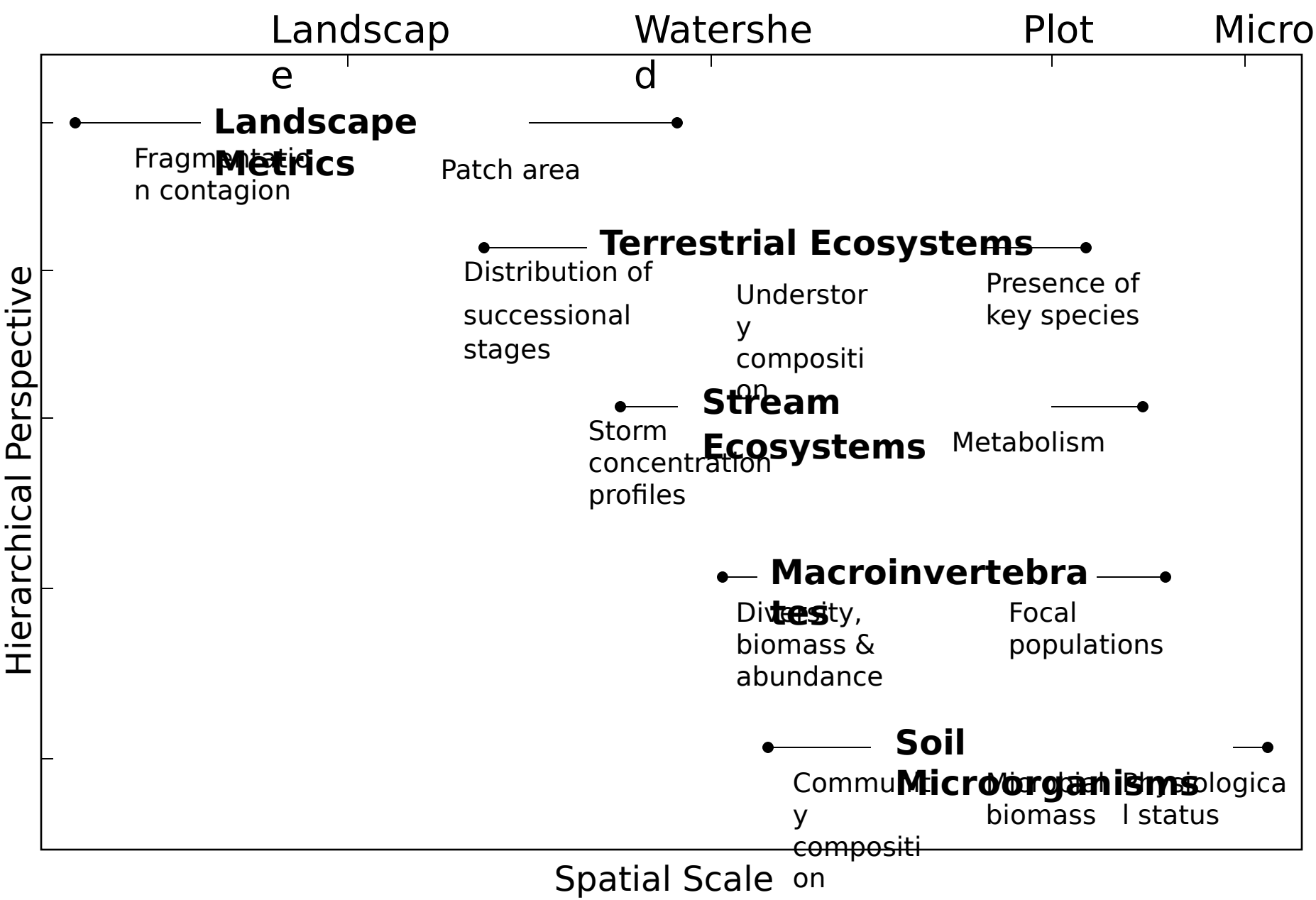
(a) Analyze historical trends in environmental changes to identify potential indicators;

(b) Collect supplemental data relating to proposed indicators (building upon existing data);

(c) Perform experiments to examine how training affects indicators;

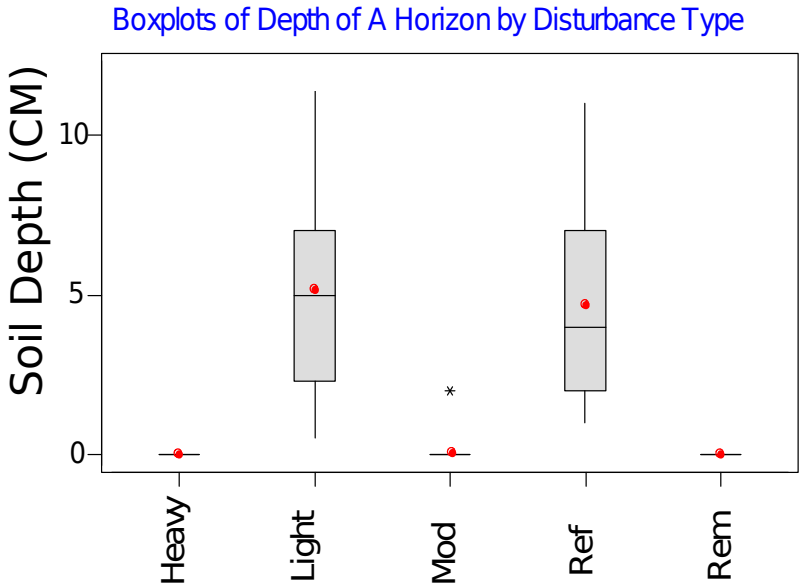
(d) Analyze resulting set of indicators for appropriateness, usefulness, and ease of taking the measure;

(e) Develop and implement a technology transfer plan.

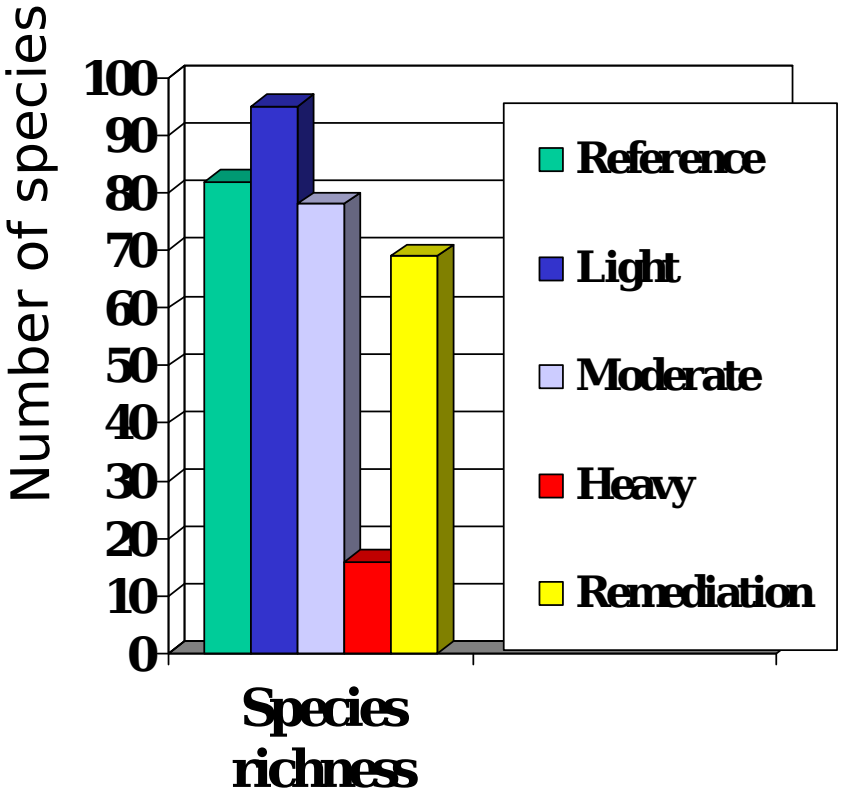

Suite of Ecological Indicators
Landscape
Watershed
Plot
Micro
Hierarchical Perspective
Spatial Scale
Landscape Metrics
Fragmentation contagion
Patch area
Terrestrial Ecosystems
Distribution of successional stages
Understory composition
Presence of key species
Stream Ecosystems
Storm concentration profiles
Metabolism
Macroinvertebrates
Diversity, biomass & abundance
Focal populations
Soil Microorganisms
Community composition
Microbial biomass
Physiological status

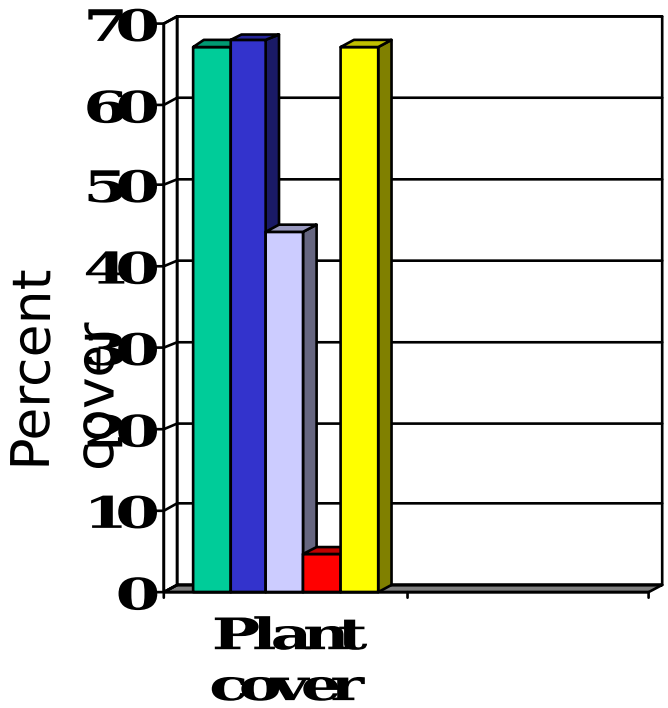
Technical Approach: Terrestrial Studies

- Objective
  - Determine indicators of ecological change due to military training
- Approach
  - Establish 5 plots along 3 transects in reference, low, moderate and high disturbance sites
  - Establish 5 plots along 2 transects in remediated sites
  - Measure understory and microbiology
  - Determine differences and

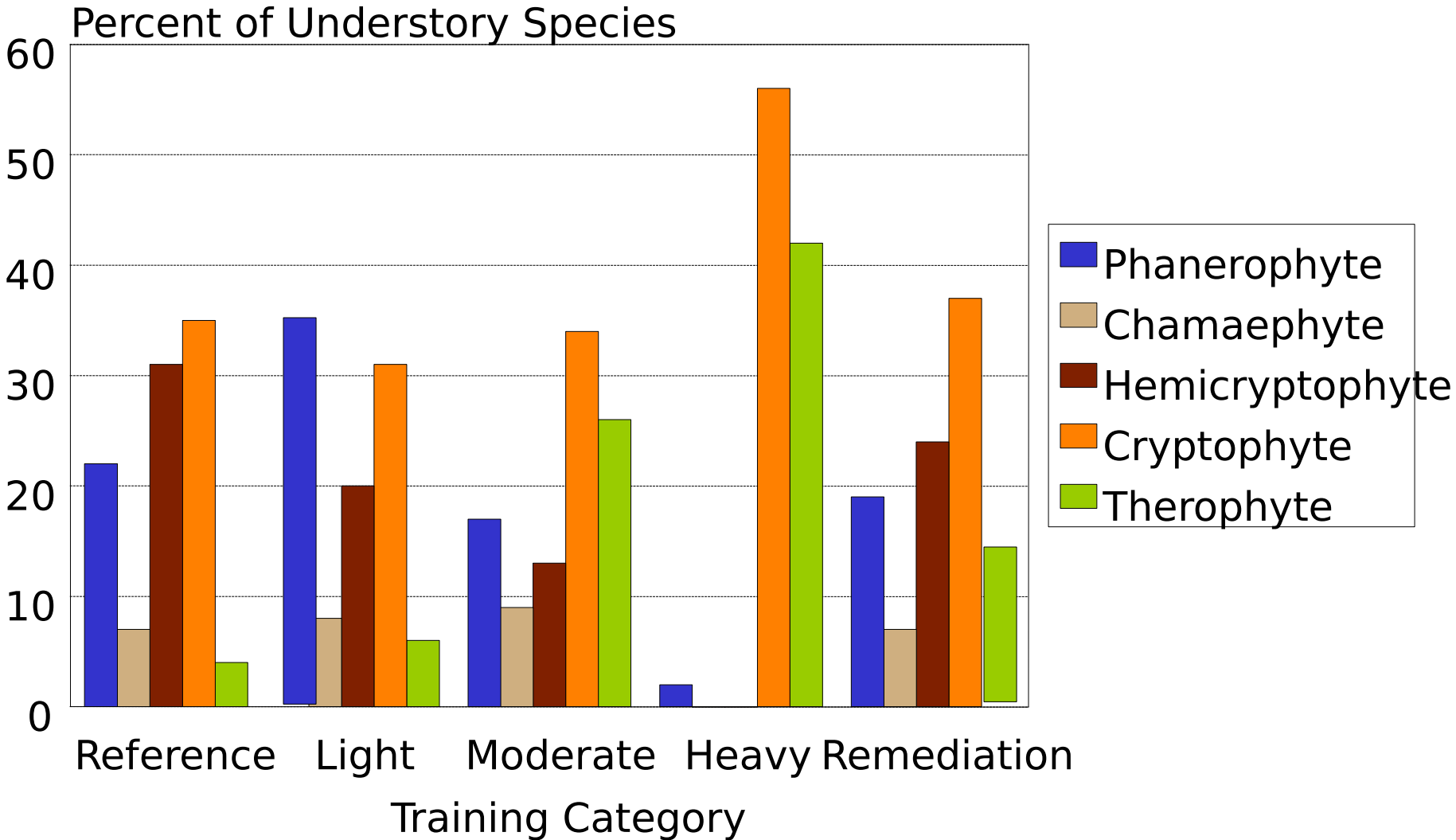


Understory characteristics of sites with different training intensities

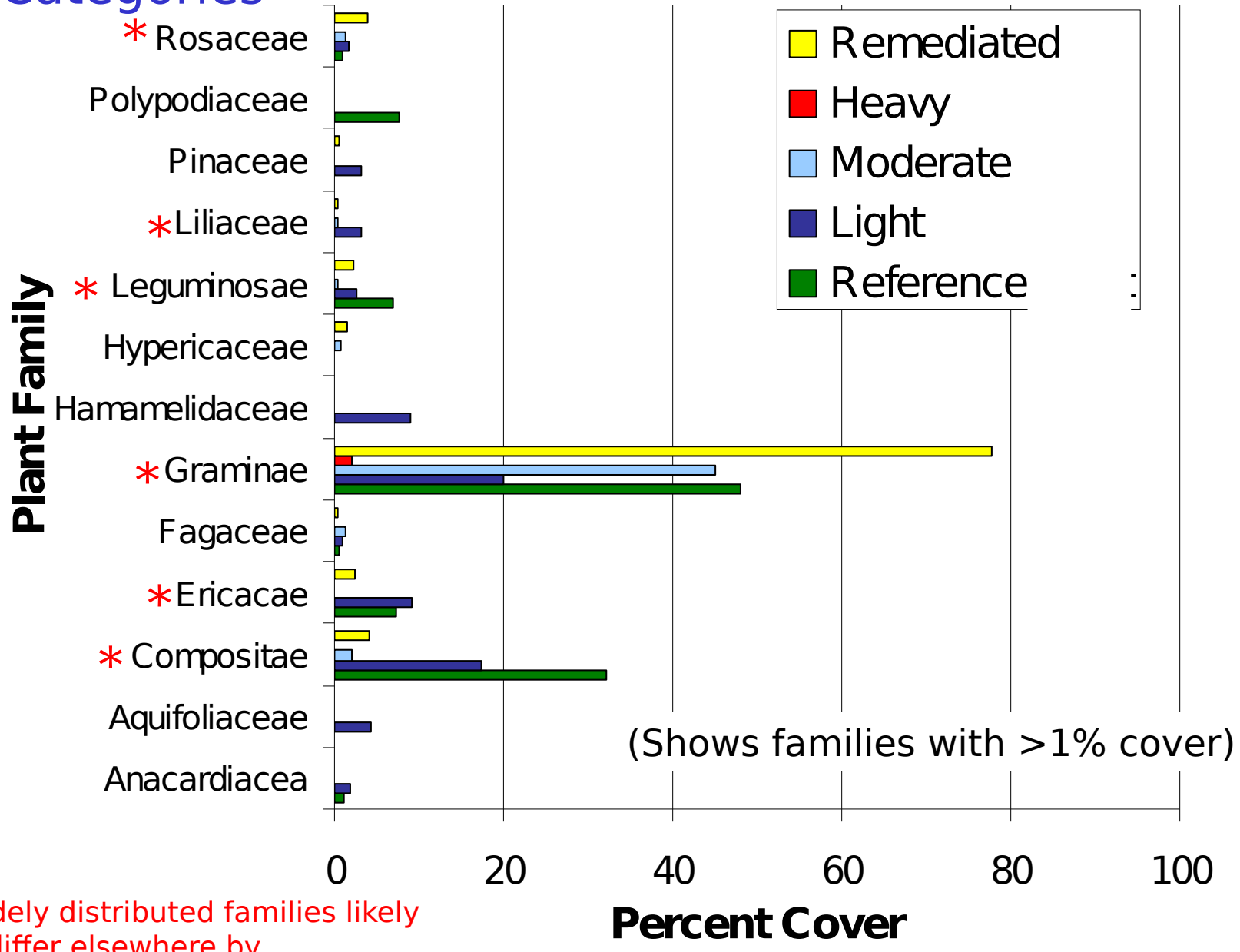




Training Categories Differ According to Life Form Distribution



Cover of Plant Families Differs between Training Categories

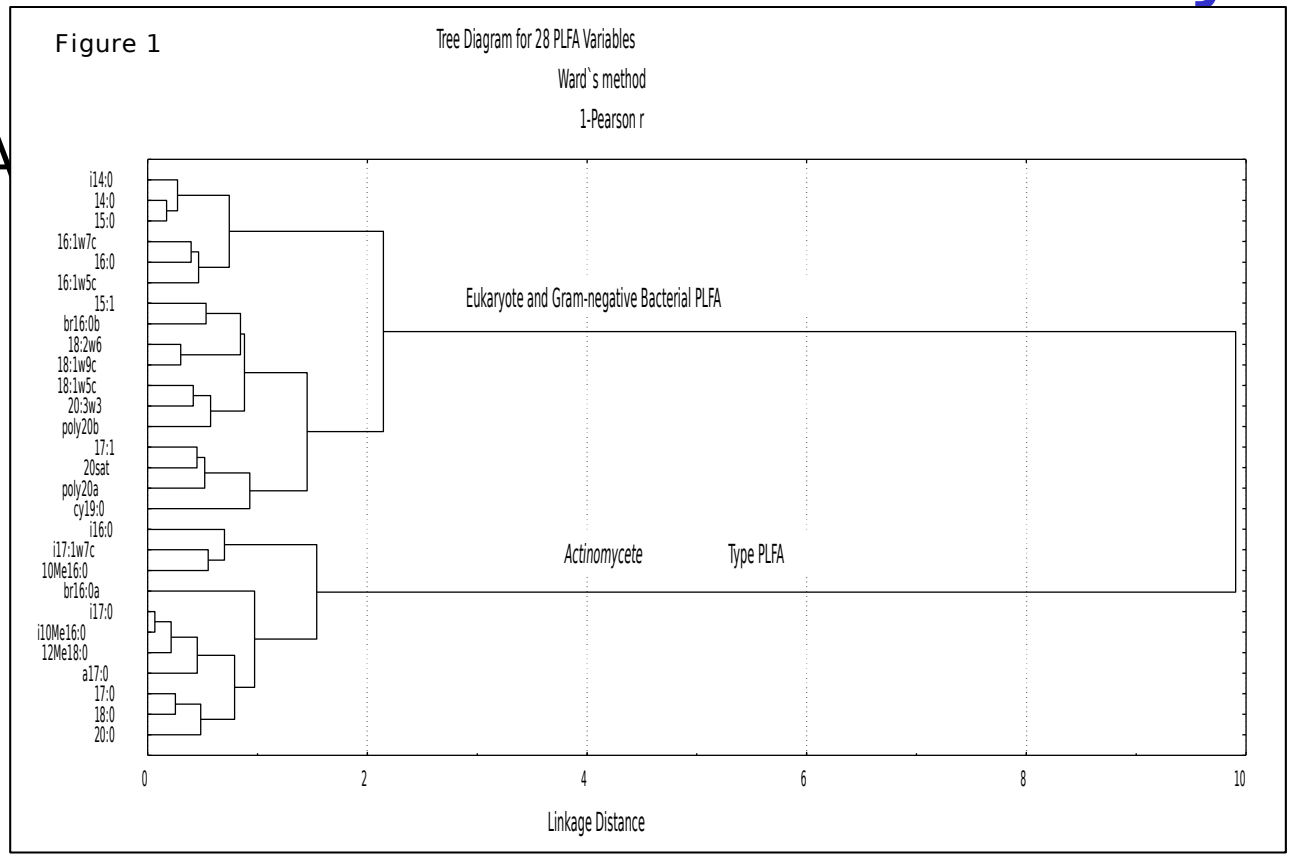


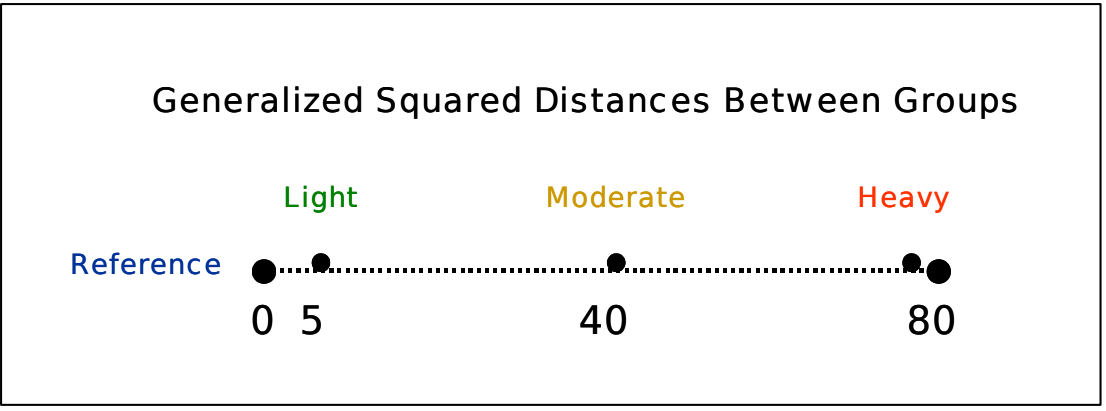
*Widely distributed families likely to differ elsewhere by

Analysis of soil microbial community

Linear discriminant model using 17 PLFA predictor variables

- Reference and light transects were very similar
- Moderate and heavy transects greatly differed



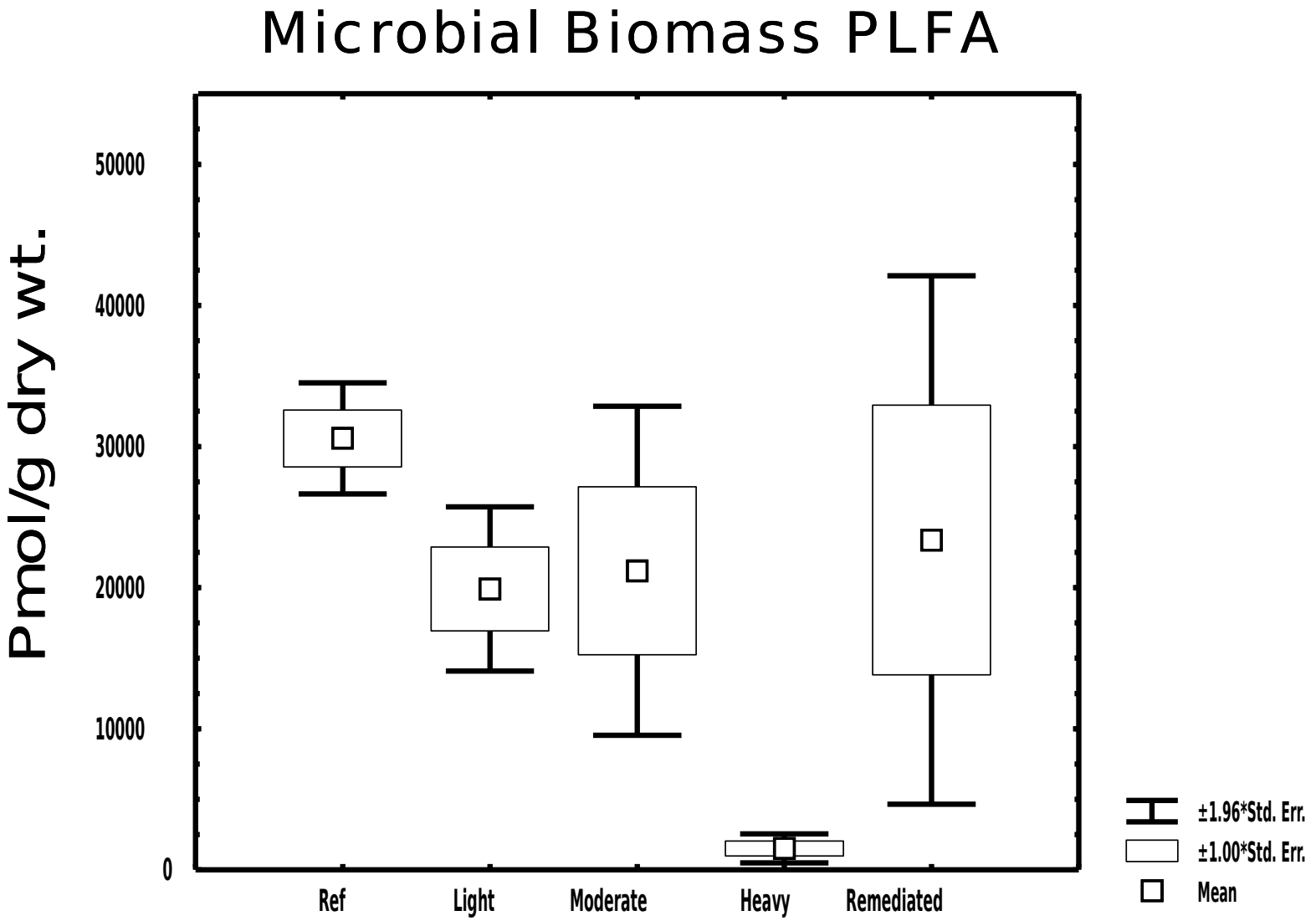


PLFAs included in the Discriminant Model

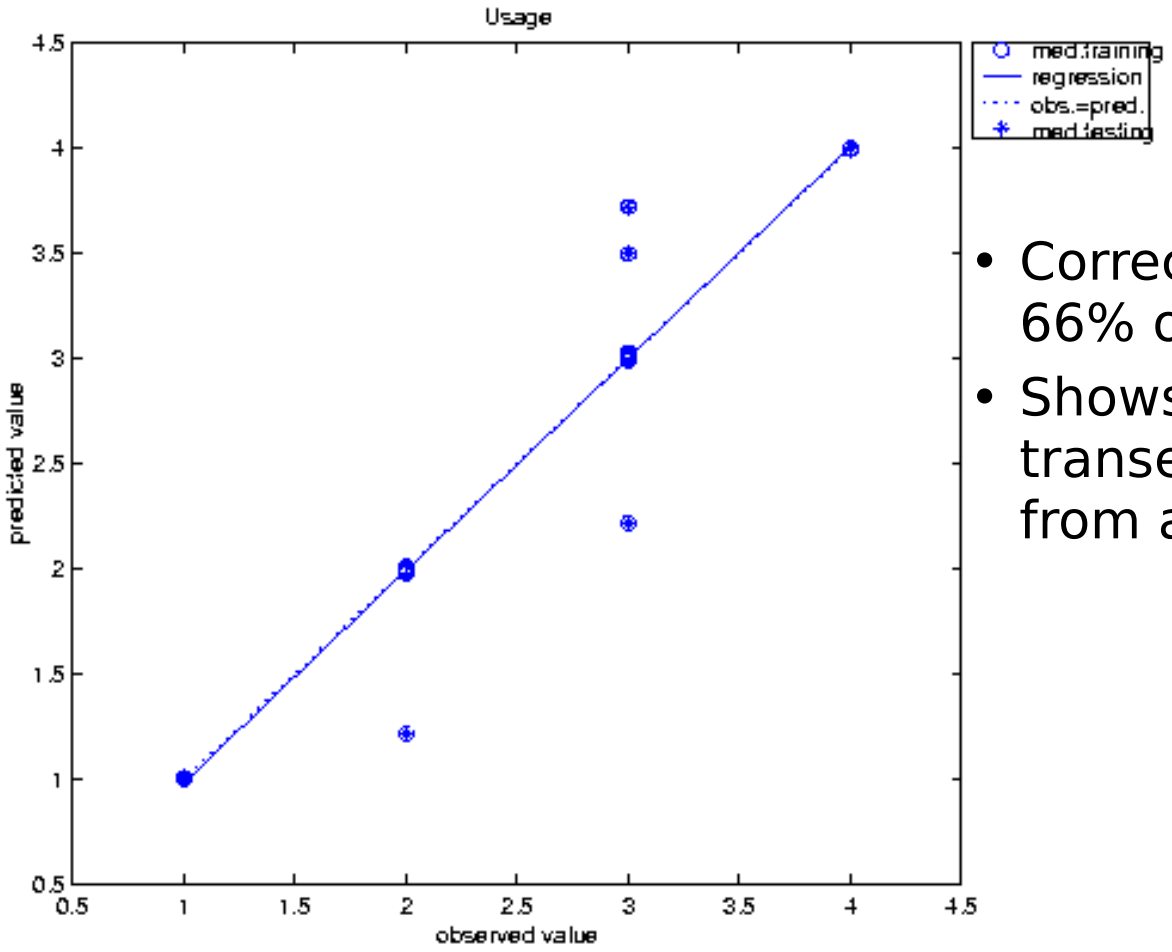
a15:0	i17:0	18:1w9c
i16:0	a17:0	18:0
16:1w7c	Cy17:0	10Me18:0
br16:0a	17:0	Cy19:0
i17:1w7c	i10Me16:0	20sat
10Me16:0	18:2w6	

The heavily disturbed site had significantly less microbial biomass.

Figure 1



Non-linear Artificial Neural Network Analysis



- Correctly predicts classification 66% of the time (25% chance)
- Shows that remediated transects are very different from all other treatments

Technical Approach: Stream Studies

Objective

Develop and evaluate potential indices of disturbance effects on catchment biogeochemistry and stream ecosystems

Approach

Disturbance gradient analysis (disturbance severity quantified at catchment scale as % land denuded)

- Stream sites (2nd-3rd order) over range of disturbance severity

- Measure potential indices across disturbance gradient

- Develop relationships between indices and

Potential Stream Indices of Disturbance

1. Storm chemistry profiles

Measurements: NH_4, NO_3, PO_4, Cl, SO_4, electrical conductance, suspended sediments over storm hydrographs

Analyses: concentration vs. discharge relationships, peak concentrations

2. Diel dissolved oxygen profiles (metabolism indicator)

Measurements: dissolved oxygen concentrations and deficits at 30-min intervals during baseflow

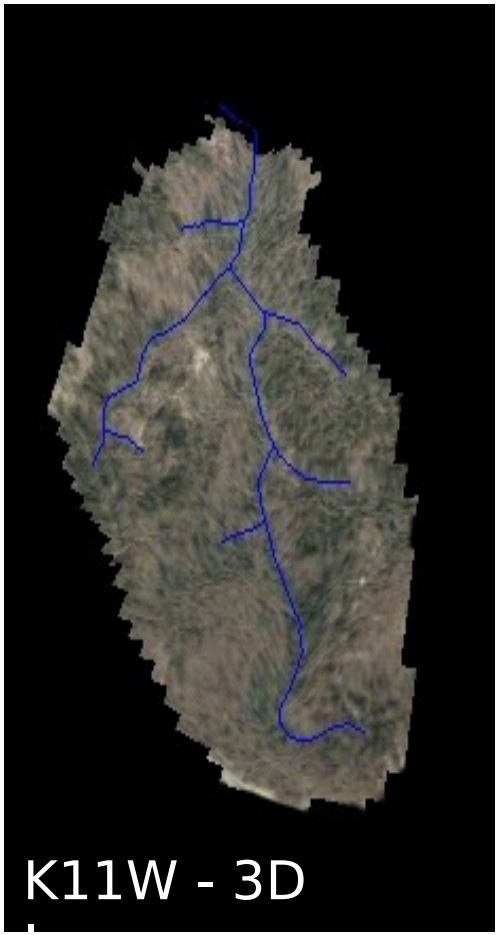
Analyses: diurnal amplitude, night-time minima

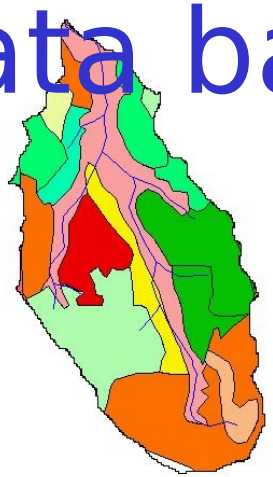
3. Macroinvertebrate communities and habitats

Measurements: numbers, biomass & diversity of benthic macroinvertebrates, bedload sediment movement

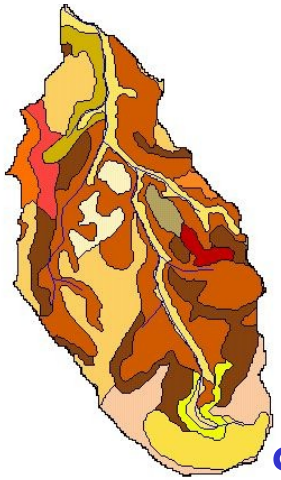
Analyses: EPT index, sensitive species abundance, NCBI index, similarity indices, sediment movement over time

Watershed Characterization-ECMI data base (GIS)

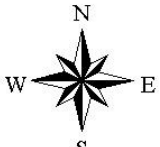




Forest cover



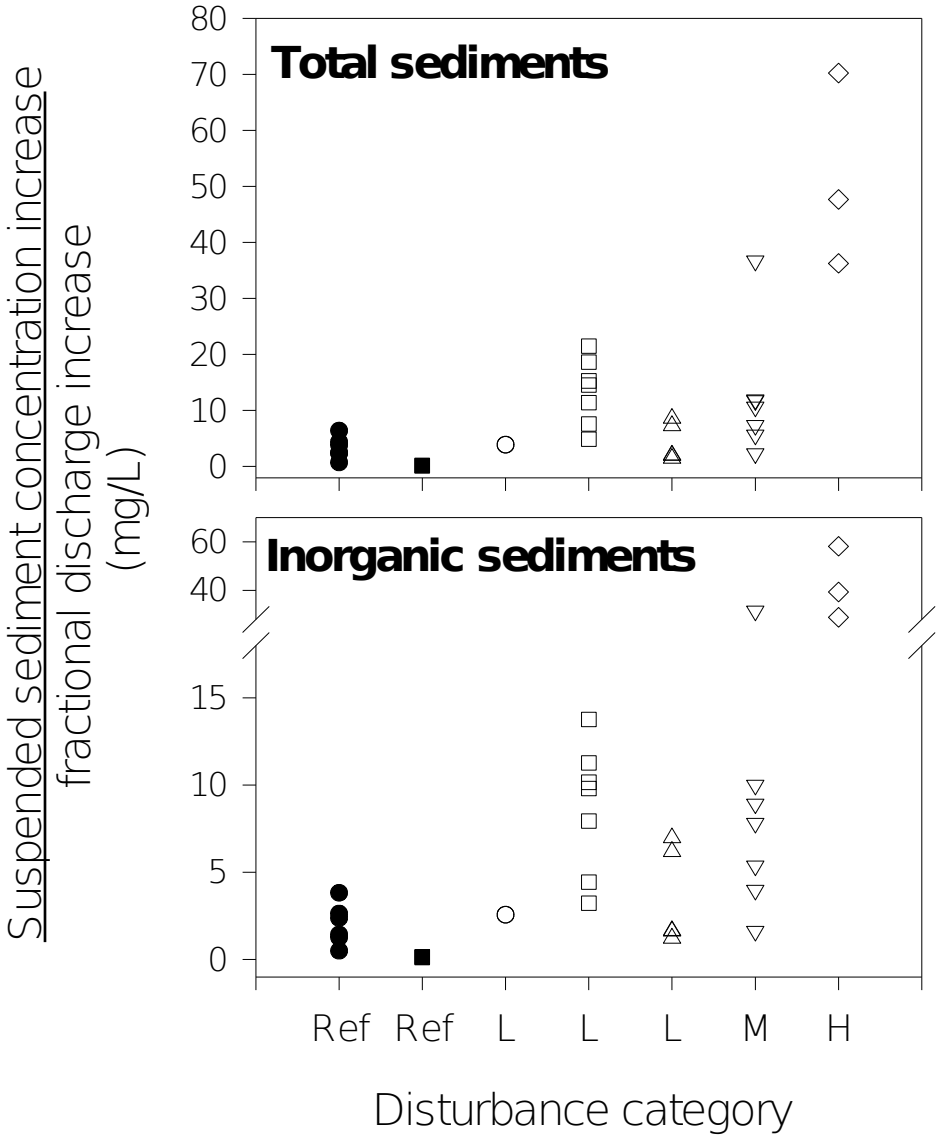
Soils



Other coverages:

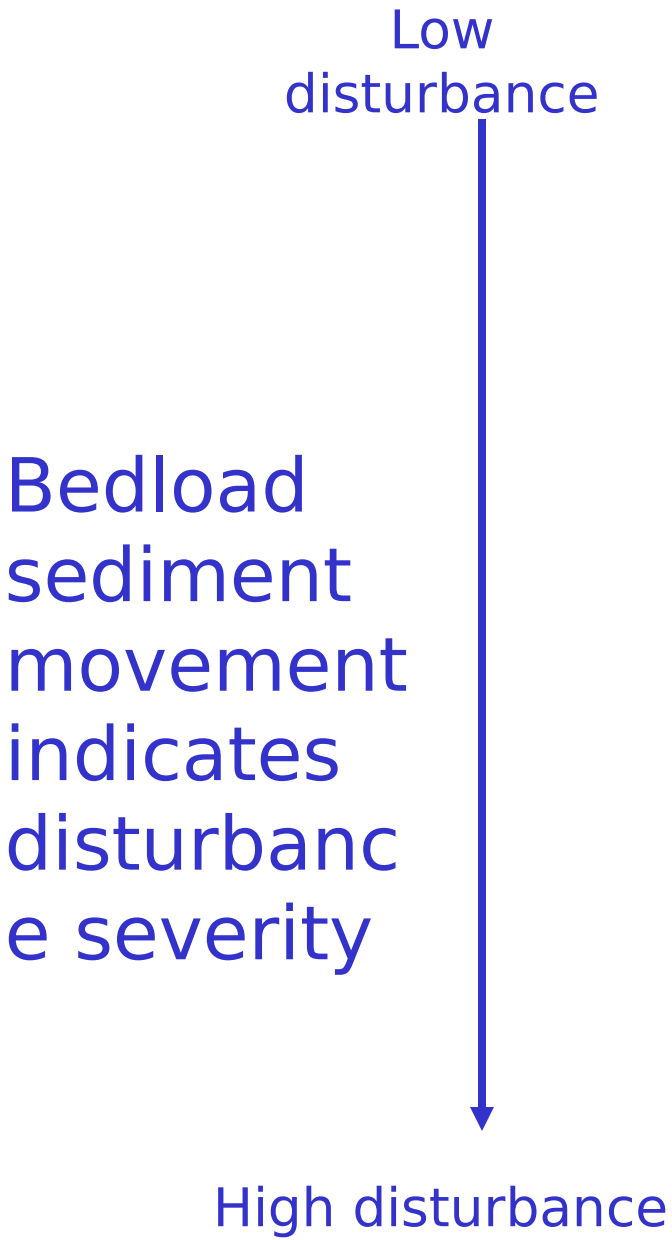
-riparian zone
-roads
-road-stream crossings
-aspect / topography
-denuded ground

Storm suspended sediment concentration increases indicate disturbance severity

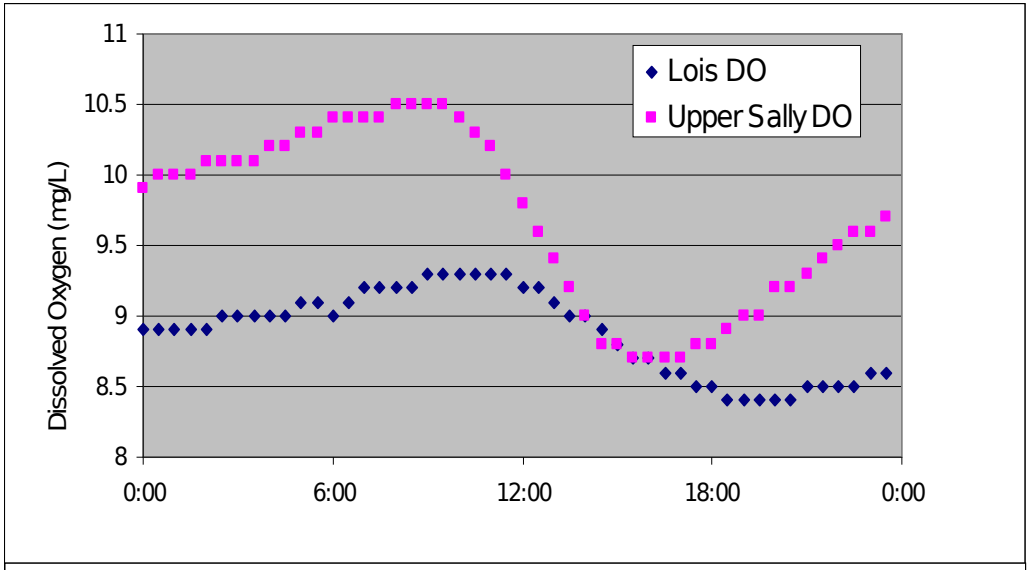


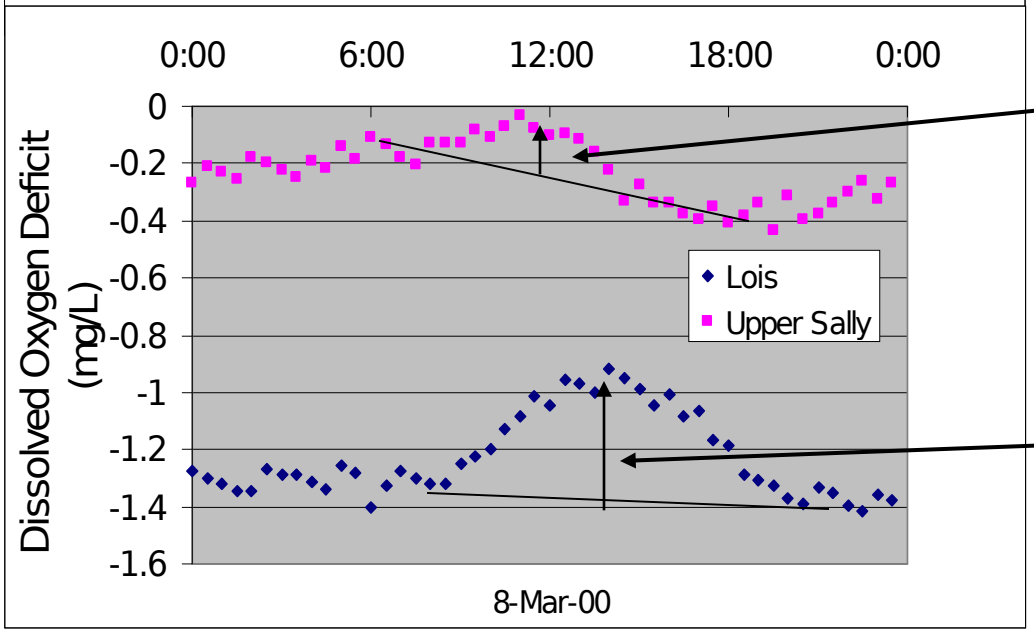
Symbols represent different storms.

Bedload sediment movement



Diurnal dissolved oxygen profiles appear a useful disturbance indicator





Low daytime primary productivity in highly disturbed stream (Upper Sally)

High daytime primary production in reference stream (Lois)

Smaller diurnal dissolved oxygen changes with greater levels of disturbance (lower algal productivity)

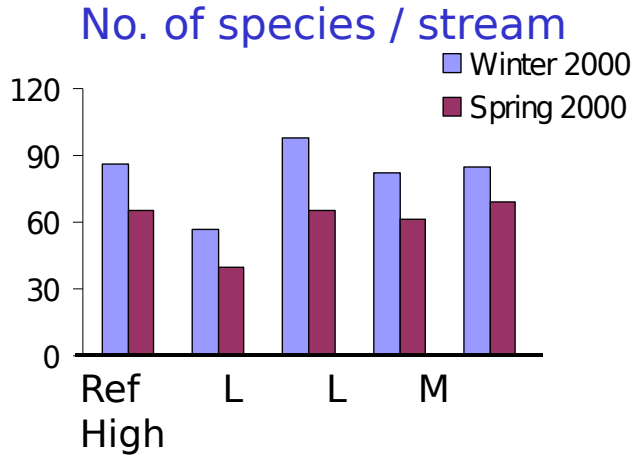
Bars are means of dates with mostly clear weather in late winter

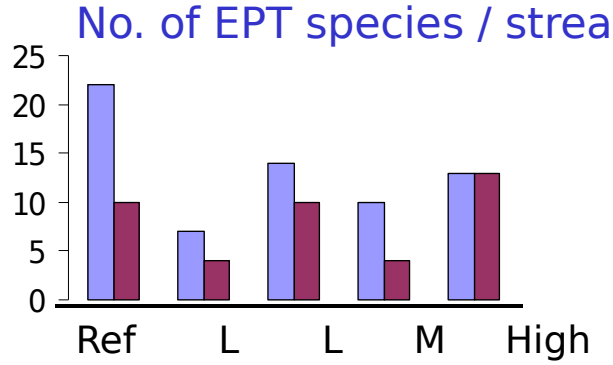
Benthic Invertebrates
(Winter & Spring 2000)

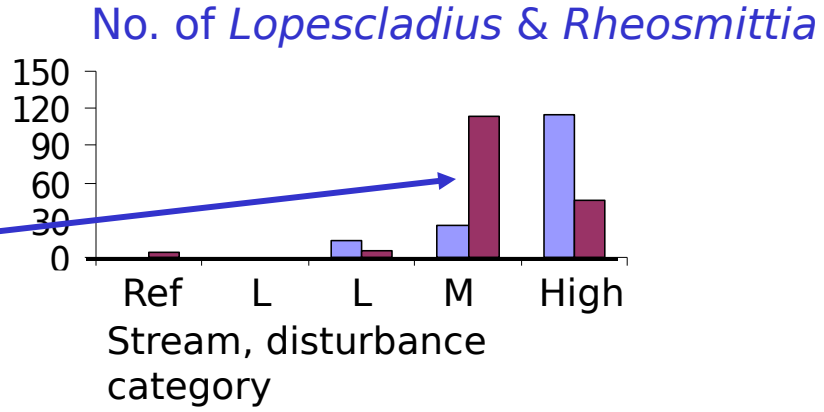
Number of total species and EPT not generally indicative of disturbance across seasons

But abundance of focal populations appears to be a useful indicator

High numbers of sediment-tolerant midges in disturbed streams







Why does the EPT indicator not distinguish between the disturbances caused by different training intensities?

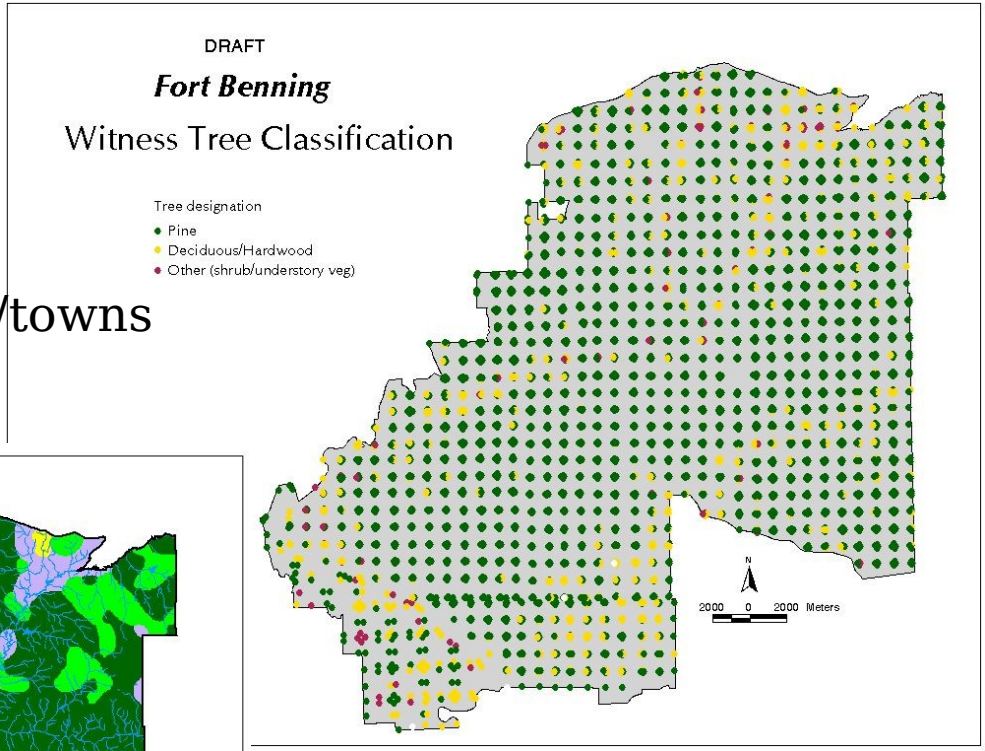
- The EPT metric was designed for use in upland streams with higher natural diversity of EPT(Ephemeroptera, Plecoptera, Trichoptera) taxa and may not work well in less diverse coastal plains streams.
  - There may be fewer species of these 3 focal groups in undisturbed streams.
  - Other researchers discovering this situation are exploring the use of new metrics with alternative focal insect orders, such as Odonata.
  - We will evaluate the efficacy of other metrics in Benning streams once we have a full array of biotic data and meaningful training intensity data for all the study watersheds.
- Alternatively, a full year of species data (rather than just 2 seasons) may be needed for EPT or other richness metrics to 'work'. (These data are preliminary).
- The metrics that are eventually determined to work best may turn out to be surprising, non-traditional ones.

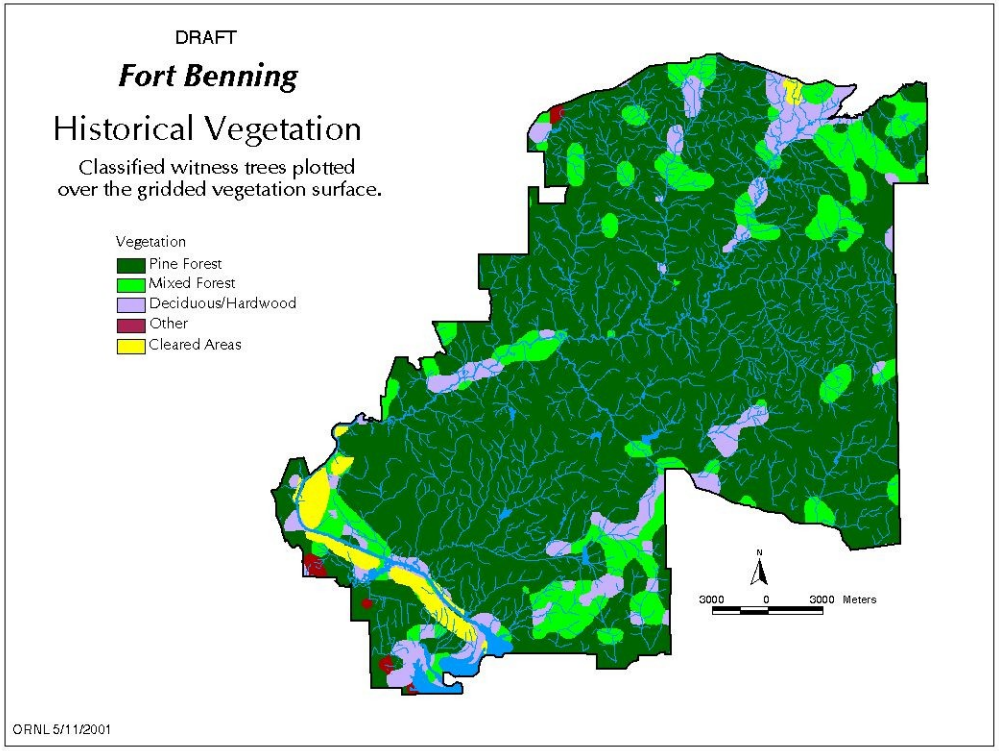
Technical Approach: Landscape Studies

- Explore data availability
- Develop comparable data sets over time
- Analyze changes in pattern and distribution of land cover over time
- Determine which landscape metrics are most useful for indicating change

Fort Benning Historical Vegetation - 1827

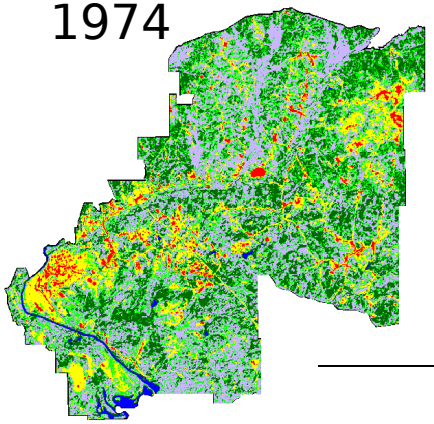
1. Witness tree data
2. Tree classification
3. Interpolation of surface
4. Estimation of cleared areas- large settlements/towns



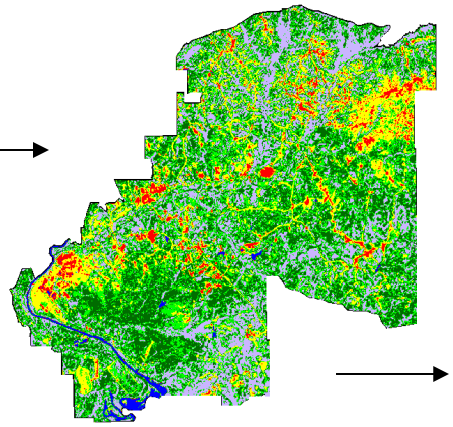


Building the Time Series

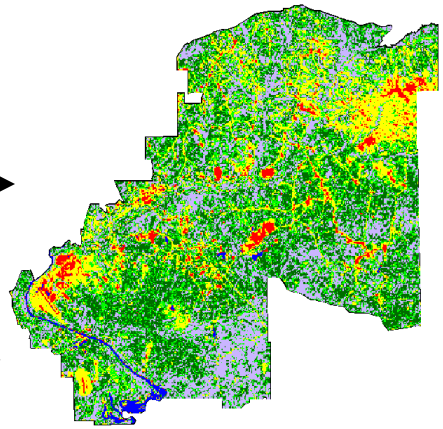
1974



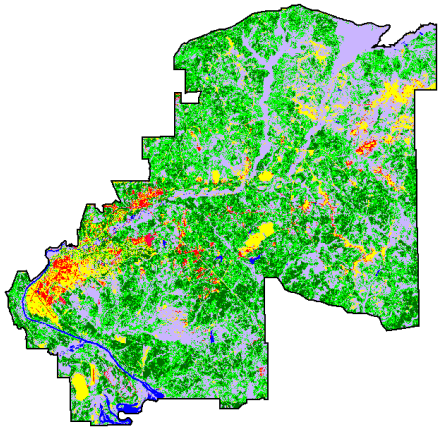
1983/86



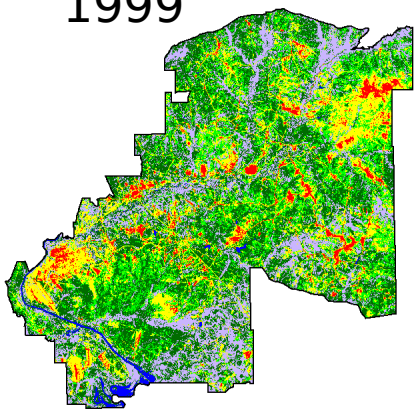
1991



1990-1993



1999



1974,1983/86, 1991-
North American Land Cover Data (NALC)
Landsat Multispectral Scanner (MSS)

1990-1993-
Multi Resolution Land Cover (MRLC) - USGS

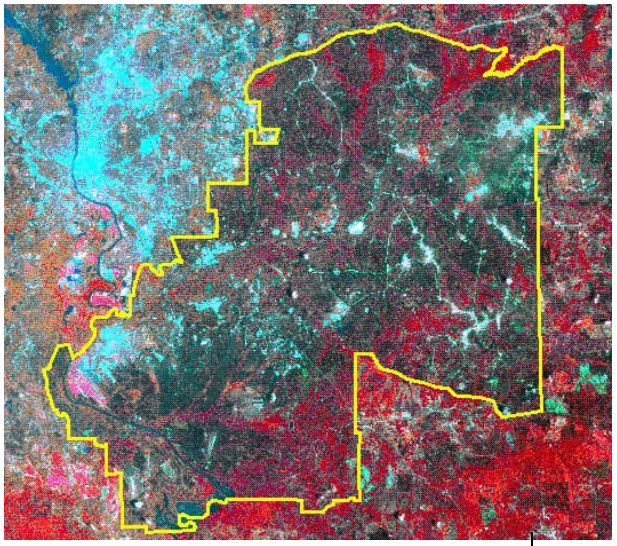
1999-
Landsat Thematic Mapper

Ft. Benning
Land Cover Classification Key

- Bare ground or developed areas such as buildings. (highly reflective surfaces)
- Non-forest or cleared areas. (ground cover present, includes lawns)
- Deciduous forest (dense)
- Mixed forest (areas of deciduous and pine, widely spaced or sparse forest cover and transitional areas between forest and non-forest)
- Pine forest (dense)
- Water

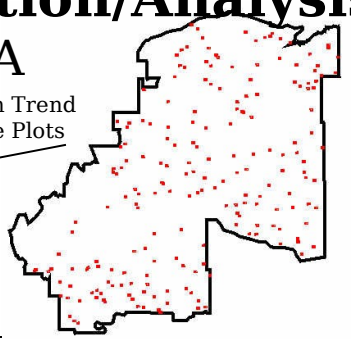
Fort Benning - Land Cover Classification/Analysis

Landsat Thematic Mapper - July 1999

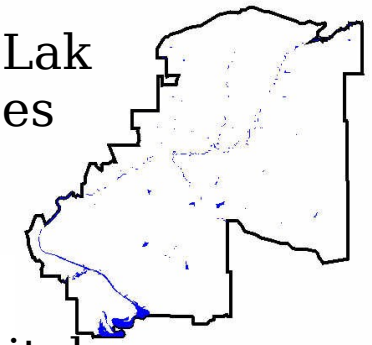


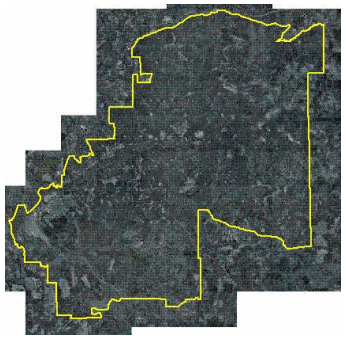
LCTA

Land Condition Trend Analysis Core Plots

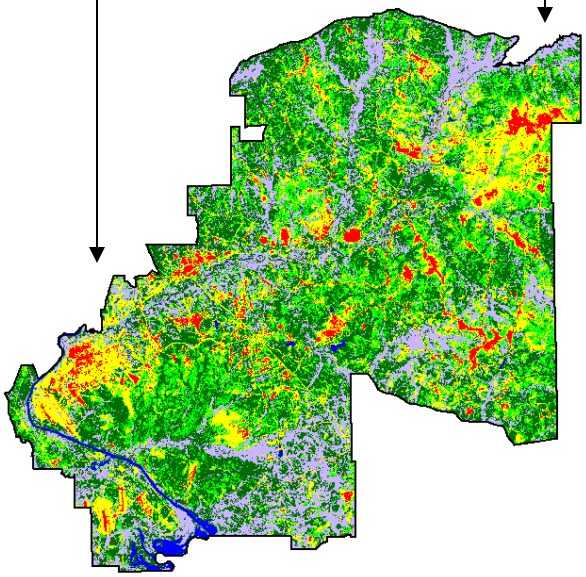


Lakes





Digital-Color Orthophoto 1999



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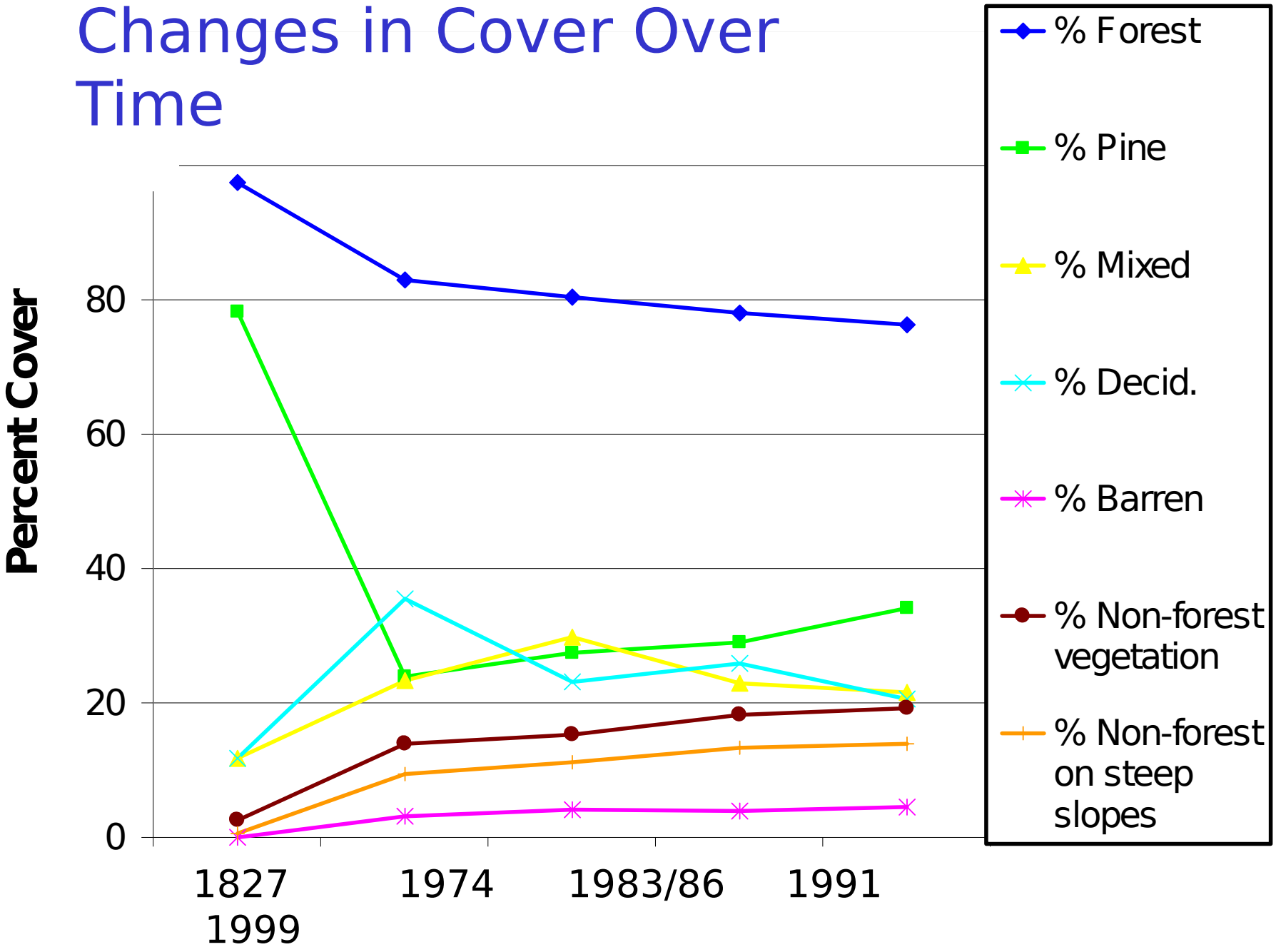
ATtILA

Analytical Tools Interface for Landscape Assessments

- -Land Use Proportion Metrics
- -Diversity Metrics
- -Forest Patch Metrics
- -Road Density Metrics
- -Riparian Characteristics

Landscape Metrics

Changes in Cover Over Time



Selected Forest Patch Metrics- ATtiLA

Metric	1827	1974	1983/86	1991	1999
# Forest Patches	3	202	238	248	395
Mean Patch Size	239,833,200	3,000,403	2,467,845	2,291,530	1,408,557
Largest Patch Size	719,348,400	563,396,400	541,213,200	525,078,000	546,213,600
Shannon-Weiner Diversity Index	0.6312	0.254	0.2381	0.2338	0.22
Simpson's Diversity Index					

Selected Class Metrics Non-Forest Class (FRAGSTATS)

Metric	1974	1983/86	1991	1999
%Landscape	13.761	15.152	18.065	18.948
#Patches	1638	1713	2175	3751
Mean Patch Size	6.201	6.529	6.129	3.729
Patch Density (#/100ha)	2.219	2.321	2.948	5.082
Total edge(m)	2,520,660	2,830,740	3,179,940	4,080,960

Next Steps

- Complete ongoing analysis
- Conduct experiment designed to test indicators
- Re-evaluate candidate indicators
- Work with Benning staff in transfer of technology

Products to Date

Publications:

- Beyeler, S.C. 2000. Ecological indicators. Master's thesis. University of Miami in Ohio.
- Dale, V.H. and Beyeler, S.C. In press. Challenges in the development and use of ecological indicators. Ecological Indicators. Vol. 1.
- Dale, V.H., Olsen, L. and Mann, L.K. In review. Contributions of federal lands to protection of endangered and threatened species. Natural Areas Journal.
- Dale, V.H. , Beyeler, S.C., and Jackson, B. In review. Vegetative indicators of anthropogenic disturbance in longleaf pine forests. Ecological Indicators.
- Foster, H.T., II and Abrams, M.D. In review. Physiographic analysis of the pre-European settlement forests in east-central Alabama. Canadian Journal of Forest Research.
- Peacock, A. D., S. J. MacNaughton, J. M. Cantu, V. H. Dale and D. C. White. In review. Soil microbial biomass and community composition along an anthropogenic disturbance gradient within a longleaf pine habitat. Ecological Indicators

Posters and Presentations

Posters:

- Dale, V.H. and Beyeler, S.C. Ecological indicators: Tools for ecosystem management. SERDP Annual Meeting, December 1999, Washington, DC
- Dale, V.H. Ecological indicators. Workshop on Ecological Models for Resource Management. October 2000, Oak Ridge TN.
- Dale, V.H. "Ecological indicators for land management. Ecological Society of America Annual Meeting, August 6, 2001, Madison, WI.

Presentations:

- Dale, V.H. Views from the Ridge: Considerations for Planning at the Landscape Scale, sponsored by the Pacific Northwest Research Station, USDA Forest Service, Vancouver, Washington, Nov. 2-4, 1999.
- Dale, V. H. Symposium on “Urban landscape ecology” at the 15th Annual US Landscape Ecology Symposium, Fort Lauderdale, Fl., April 15-19, 2000.
- Dale. V.H. EcoSummit 2000: Integrating the Science. Halifax, Nova Scotia, Canada, June 18-22, 2000.
- Dale, V.H. Using indicators for restoration and management. Ohio State University. November 2, 2000.
- Dale, V.H. Lessons for Ecosystem Management. Fall Line Workshop. March 6-7, 2001, Aiken, S.C.
- Dale, V.H. Use of indicators. Workshop on “Climate Change and Species Survival: Implications for Conservation Strategies,” February 19-21, 2001, The World Conservation Union (IUCN) in Gland, Switzerland.
- Dale, V.H. “Top Ten Issues in Landscape Ecology” session at the 16th Annual Symposium on Landscape Ecology, Tempe Arizona, April 2001
- Foster, T. "Evolutionary Ecology of Creek Residential Mobility," Southeastern Archaeological Conference, Macon, Georgia, November 2000.
- Olsen, Lisa M. and Virginia Dale. Landscape Patterns as Indicators of Ecological Change at Fort Benning, GA. ESRI User Conference, July 9-13, 2001, San Diego, CA.

Integration

Contributions to Other SEMP Projects

- Criteria for selecting a suite of indicators
- Protocol for selecting indicators
- Data from our studies on indicators: terrestrial, stream, and soil microbes
- Historical vegetation map

Coordination with Other SEMP Projects

- Baseline information provided by ECMI and LCTA
- Co-location of sampling sites and sharing of data with other SEMP projects
    - Storm hydrological chemistry
    - Stream macroinvertebrates
    - Soil samples
- A comprehensive picture of changes in microbial community structure

Coordination with Other SERDP Projects

- "Application of Hyperspectral Techniques to Monitoring and Management of Invasive Weed Infestation" will use hyperspectral data (primarily AVIRIS) to map and model the spread of invasive weeds at Fort Benning in coordination with our site specific data
- "A Regional Simulation to Explore Impacts of Resource Use and Constraints" will build upon our data and other ECMI information to integrate environmental effects of on-base training and testing and off-base development and other decisions
- "Riparian ecosystem management at military installations determination of impacts and evaluation of restoration and enhancement strategies" will co-locate some stream sampling sites and use some of our stream ecological indicators.